



## **Influence of Vehicular emissions on air quality in Metros of India**

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### **Abstract**

*City formation is an integral part of development process. It is expected that, around 73% of the world's population would have become urban by the year 2050 (World urbanization prospects 2007). Three out of the top ten mega cities of the World are located in India and thirty five cities have a population of more than 1 million each. Haphazard industrialization, lack of town planning and in-efficient public transport systems, coupled with the economic growth has led to a shift in the mode of transport from public to private or transit vehicles. It is also seen that along with population the number of vehicles plying in the city are increasing exponentially. For example: Kolkata a mega city having an area of 1246 km<sup>2</sup> with a high vehicle density (5685 per km<sup>2</sup>). In December 2002, the number of vehicles registered with the Public Vehicles Department was about 0.8 million, with 40,000–50,000 vehicles being added each year ([Asian Development Bank, 2005](#)), which has led to problems such as traffic congestion or traffic jams, which in turn has lead to increase in concentration of air pollutants in a particular area or at the site of traffic jams.*

*This has raised concerns about the air pollution phenomenon and its subsequent effects on plants, animals and human health. According to Cofala et al. (2007), in the year 2000, the road transport accounted for 33% of the sources of NO<sub>x</sub> emissions of the world. Also the number of cases of Lung disorder has increased drastically, cases registered for asthma and bronchitis.*

*The current study aims at finding out the influence of vehicular traffic on the concentration of the criteria pollutants [Oxides of Nitrogen (NO<sub>x</sub>), Oxides of Sulphur (SO<sub>x</sub>), Respirable Suspended Particulate Matter (RSPM) and Suspended Particulate Matter (SPM)], in Major Cities of India. As a part of the study, an extended survey was carried out by monitoring of ambient air quality (along with ground level ozone) and vehicular survey in order to find out the co-relation between vehicular emissions and concentration of air pollutants in the city of Mumbai.*

**Key words:** Metropolitan cities, vehicular emissions, criteria pollutants.

## 1. Introduction

City formation is an integral part of developmental process. Three out of the top ten mega cities of the World are located in India and Thirty five others have a population of more than 1 million. It is also seen that along with population the number of vehicles plying in the city are increasing exponentially. For example: Kolkata a mega city having an area of 1246 km<sup>2</sup> with a high vehicle density (5685 per km<sup>2</sup>). The shift to private mode of transport over slow moving public transport is very sharp and with the help of growing economy more and more people are purchasing smaller vehicles like 2-wheelers and small cars. Moreover vehicular emissions account for about 60% of the GHG's from various activities in India, (Patankar, 1991). The worst thing about vehicular pollution is that it cannot be avoided as the emissions are emitted at the near-ground level where we breathe. The different air pollutants due to vehicles can have effects at all the three levels – local (e.g., smoke affecting visibility, ambient air, noise etc.), regional (such as smog, acidification) and global. The vehicles besides being the prominent source of air pollutants also account for a number of external effects, such as congestion, noise, accidents, and road wear and tear, etc. It has been observed that among different type of motor vehicles, percentage of two wheelers has shown rapid growth (doubling in every 5 years) and it constitutes 70% of total motor vehicles of India (MoSRTTH, 2004). This has raised concerns about the air pollution and its subsequent effects on plants, animals and human health.

The current study aims to find the influence of vehicular traffic on the concentration of the criteria pollutants [Oxides of Nitrogen (NO<sub>x</sub>), Oxides of Sulphur (SO<sub>x</sub>), Respirable Suspended Particulate Matter (RSPM) and Suspended Particulate Matter (SPM)], in the 5 major cities of India. As a part of study an extended survey was carried for monitoring ambient air and ground level ozone along with vehicular count in order to find out the co-relation between vehicular emissions and concentration of air pollutants in the city of Mumbai.

## 2. Materials and Methods

For the study, five major metropolitan cities of India, namely, Bangalore, Chennai, Delhi, Kolkata and Mumbai were considered. The work is based on secondary data which was obtained from various publications of government of India. Data was collected for number of vehicles registered in the city, population of the city and vehicle density of the city. Along with this, data was also collected for pollution levels of the criteria pollutants from 2004-2007 to match with the vehicle population.

As a part of the study an extended vehicular count was carried out for the city of Mumbai for a week, in the month of May 2009 with simultaneous sampling of air pollutants such as NO<sub>x</sub>, SO<sub>x</sub>, SPM, RSPM and ground level ozone. The site selected for the survey was the traffic junction near the sampling station of NAQM at Worli. The vehicles moving from the Worli junction towards Dr. Annie Besant road were counted during the peak hours of morning, i.e., from 8 a.m. to 12 noon, whereas ground level ozone concentrations were monitored for entire month.

### **3. Vehicular ownership in India**

The relationship between the growth of vehicle ownership and per-capita income is highly non-linear. The growth of vehicles follows approximately a Gompertz function (Joyce Dargay 2007). Motor vehicle numbers have grown even more rapidly in the cities than nationally. Urban motor vehicle growth rates have far exceeded urban population growth rates, which themselves have been dramatic (Singh Sanjay 2005). The area occupied by roads and streets in Class I cities (population more than 100,000) in India is only 16.1 percent of the total developed area, while the corresponding figure for the United States is 28.19 percent (Singh Sanjay 2005). As far as the public transport system in Indian cities is concerned, dedicated city bus services are known to operate in 17 cities only and rail transit exists only in 5 cities (Mumbai, Delhi, Chennai, Hyderabad and Kolkata) out of 35 cities with population in excess of one million. This lack of public transport system has forced people to own vehicles and out of the total number of vehicles, maximum are two-wheelers as they are much economical than other categories in terms of cost, maintenance and fuel efficiency. Due to this the number of vehicles per 1000 has shown an increase from 2/1000 (1991) to 12/1000 (2008).

If the above stated trend would continue and fuel economy norms are not implemented strictly then the urban environment would undergo drastic changes and pollution levels would remain above prescribe standards throughout the year as in case of Delhi where surveys have shown that the daily average suspended particulate levels, which is strongly correlated with respiratory and cardiovascular diseases, exceeding World Health Organization (WHO) guideline limits almost daily in Delhi (CPCB, 1996, 2004).

### **4. Status of vehicular pollution in the megacities of India:**

**4.1 Bangalore:** In Bangalore the sources of air pollution are vehicular, industrial, commercial and domestic activities. The point sources of pollution are mainly large and medium scale industries involving processes and large number of D.G. sets causing large scale air emissions, while automobiles constitute the major non-point polluting source. The problems associated with air pollution in Bangalore are mostly due to the large number of privately owned motor vehicles (vehicles of obsolete two stroke technologies, road congestion, poor public transit system, bad maintenance etc.) Moreover the absence of an efficient local transport system provided by the Bangalore Metropolitan Transport Corporation (BMTC) has compounded the problem.

Due to this it is observed that the share of privately owned vehicles especially two wheelers is steadily increasing every year, for example the percentage of two wheelers in the year 1985 was 67.67%, whereas in the year 2002 it increased to 74.14% out of all the vehicles registered in the city. On the contrary the share of buses was meagre 1.32% in 1985 which dropped 0.63% in the year 2002. Another aspect to be noticed is that the total number of vehicles for Bangalore in 1985 was 2, 88,466

which have grown seven folds over the period reaching 15, 96,558 in 2002. Along with the rise in vehicle population the concentration of air pollutants is bound to increase. It has been observed that NAAQS (24 hourly average) of SO<sub>2</sub> and NO<sub>2</sub> are not violated at almost all the monitoring stations. NAAQS (24 hourly average) of RSPM are violated at many monitoring stations especially in residential areas. NAAQS (24 hourly average) of SPM are violated in residential areas (CPCB, 2007).

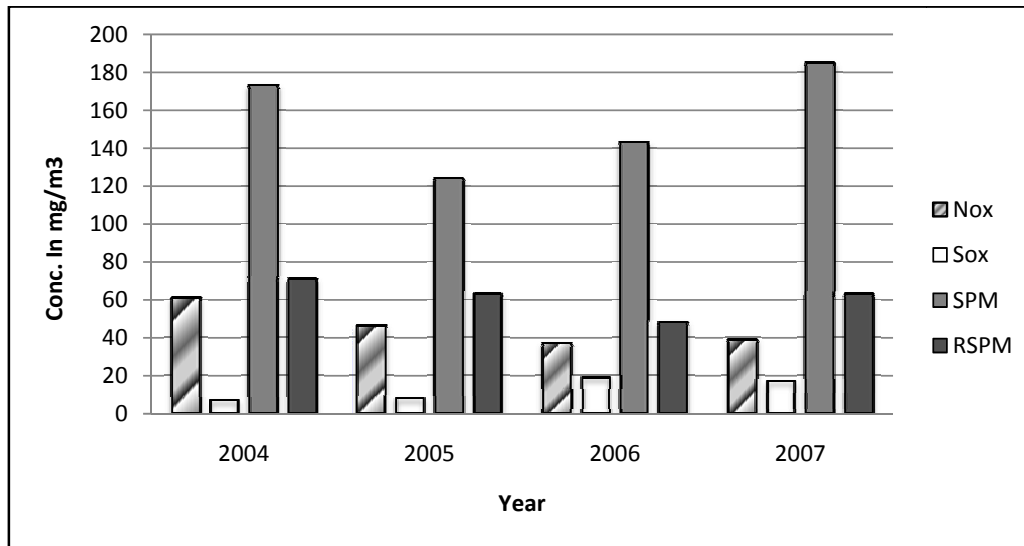


Figure 1 Concentration of criteria pollutants in Bangalore.

Source: CPCB 2007

The figure 1 shows that the SPM values exceed the prescribed limit at majority of the monitoring stations especially in residential areas, which can be explained by the higher vehicular activity in that area. The levels might go beyond 200 on an average in the next couple of years. Every year the levels of SO<sub>x</sub> are slowly rising in the residential areas, the highest values were recorded for the year 2006 (19 µg/m<sup>3</sup>).

**4.2 Chennai:** With the increasing commercial and industrial activities, the transport system is also increasing day by day in Chennai City. As a result, traffic congestion has steadily increased causing acute shortage of parking space and deterioration in quality of air. The levels of SPM and RSPM are of major concern as the levels are steadily increasing year after year. This can be explained by the fact that the rise in number of vehicles has led to rise in the particulate matter concentration in the atmosphere. In Chennai there are no restrictions on the movement of out-dated vehicles unlike Mumbai; moreover the metrology of Chennai plays an important role in contributing to the pollution levels of Chennai in addition to man-made sources (CPCB 2007). As the city of Chennai is located adjacent to the coast, the strong wind conditions prevailing almost throughout the year contribute to the dispersion of air pollutants and its concentration. RSPM was violated in residential areas which may be due to emission from vehicles, re-suspension of road-dust, emission from industries etc. The preventive measure for vehicular pollution are now being formulated and worked upon by the government.

**4.3 Delhi:** Against 1.9 million vehicular population in 1990 in Delhi, it rose to nearly 3.6 million in the year 2001 (i.e., an increase of nearly 87%). During the same period, Delhi's population has increased by only 43% (from 9.5 million to 13.8 million) and road-length by merely 14% (from 22,000 Km to 25,000 Km) respectively. This indicates the exigency of controlling vehicular pollution. Whether it is banning of registration of 2-stroke engines or switching to CNG by public transport or timers at

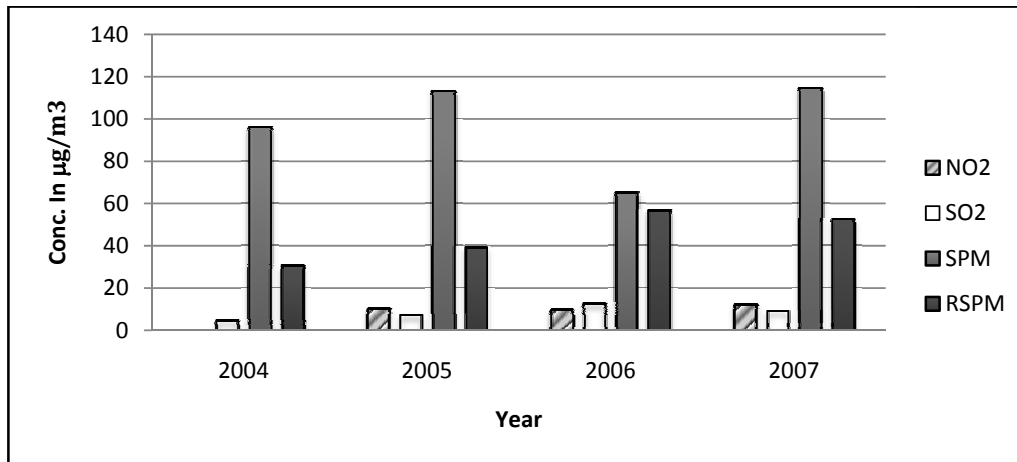


Figure 2 Concentration of criteria pollutants in Chennai

Source: CPCB 2007

Intersections or lanes for HOVs etc, maximum measures are been taken in the capital in order to control air pollution. In spite of that air pollution in the city of Delhi is persistent. The fig.3 shows the increase in the concentration of SPM. The SPM is not homogenous; it has a number of constituents. As a result, it is measured and characterised in various ways: (i) TSP (Total suspended particulates) with particle diameters  $< 50-100 \mu\text{m}$  is the fraction sampled with high-volume samplers. (ii) PM: Inhalable particles having a diameter  $< 10 \mu\text{m}$  penetrates through the nose, by breathing. (iii) Thoracic particles: are approximately equal to PM particles. (iv) PM: 'Fine fraction' with a diameter  $< 2.5 \mu\text{m}$  penetrates to the lungs; and (v) Black smoke: a measure of the blackness of a particle sample gives a relative value for the soot content of the sample. Due to their high health damaging potential recent studies have started paying more attention to  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  particles.

Fig. 3 also depicts the pollution trend over the last four years in New Delhi and the results for the capital of India are not at all pleasing because of the high levels of SPM throughout the year. According to a study in Delhi one out of every 10 school children suffers from asthma that is worsening due to vehicular pollution (CPCB 1999). The levels of  $\text{NO}_x$  are slowly creeping upwards with the rise in the number of vehicles increasing every year in the city. The growth vehicles in depicted in Fig.4 which shows an average annual growth rate of 8.003% per year and the number of vehicles per 1000 individuals jumped from 192 (1995) to 295 (2006) (Transport Department, Government of NCT of Delhi). If this trend continues then in 2020 the number of vehicles per 1000 individuals would grow to 449 vehicles per 1000 individuals. The SPM concentration thus would reach up to an annual average  $500 \mu\text{g}/\text{m}^3$ .

**4.4 Kolkata:** Kolkata and Howrah, the twin cities situated on the eastern and the western side of the river Hooghly. Due to the availability of infrastructural facility which included river fronts. The city has a port and an abundance of water and raw materials for industrial activity such as coal. Due to availability of raw materials and resources rapid industrialization has taken place in Kolkata from the pre-independence period

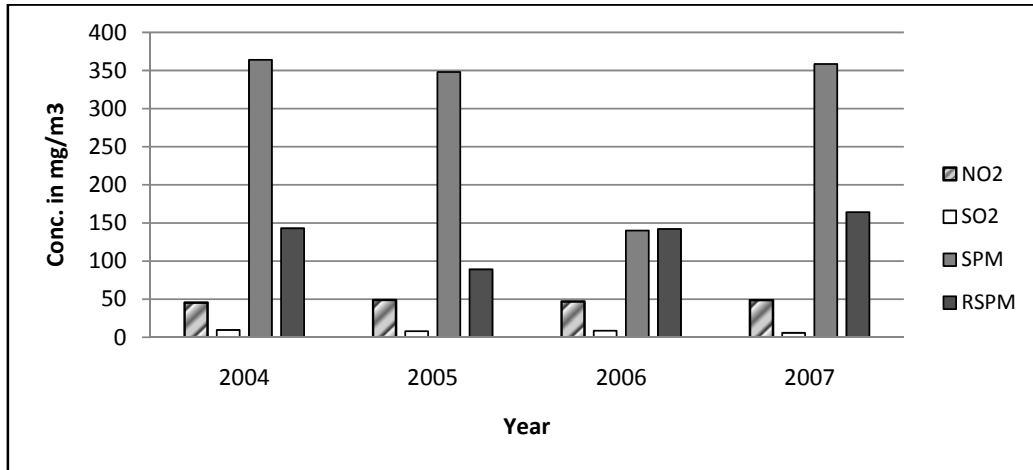


Figure 3 Concentration of criteria pollutants in Delhi.

Source: CPCB 2007

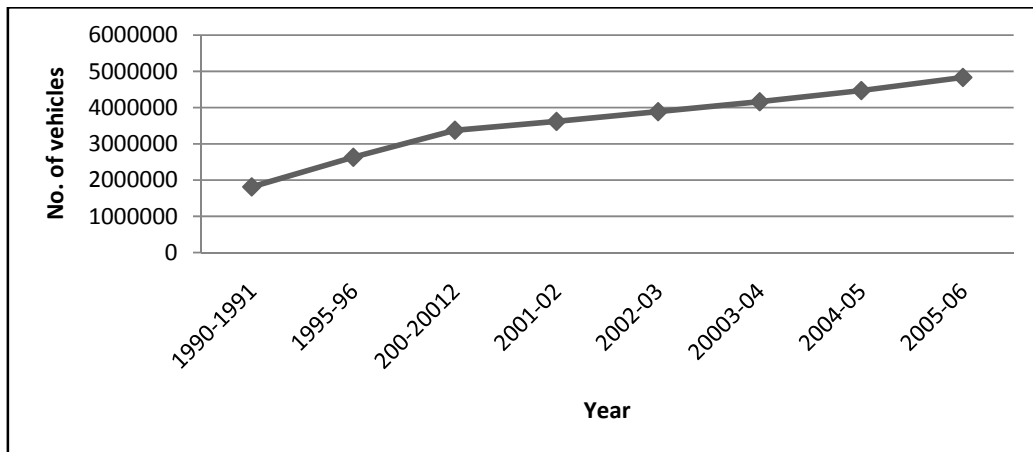


Figure 4 Number of vehicles in New Delhi

Source: Transport Department, Government of NCT of Delhi.

As most of these industries were built long before they have outdated technology and hence generate various forms of emissions in large quantities. Industrial emissions in the city and its suburbs are caused by coal burning in thermal power plants and other industries. Besides, the emissions from rapidly increasing numbers of vehicles are also largely responsible for the high level of air pollution in the atmosphere. Over the last decade the number of registered automobiles in Kolkata has increased by 52 percent. The conditions in Kolkata are so worse that the effective road area available in Kolkata is less than 5 percent of the total area (CPCB 2007). Very high automobile density, disproportionately low percentage of road network, congestion and traffic jams aging vehicles and unscientific traffic management are the major reasons for high emission of air pollutants from automobiles. The fig. 5 shows the trends of

ambient air quality over the past four years in Kolkata. Except for  $\text{SO}_2$  and  $\text{NO}_x$ , the pollution norms for all other monitored pollutants have been violated for all the years shown in graph. Also other studies on air pollution at traffic intersections by

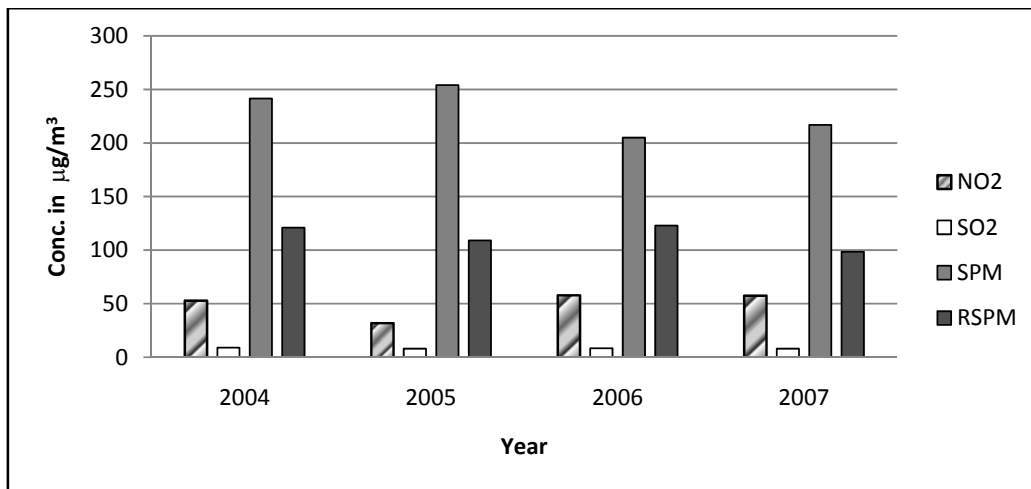


Figure 5 Concentration of criteria pollutants in Kolkata.

Source: CPCB 2007

Ghose Mrinal (2004) revealed that the concentration of the mean SPM concentration at the traffic air quality monitoring station ranged around  $739.3\mu\text{g}/\text{m}^3 \pm 20\%$ . This concentration exceeds the permissible limit of Central Pollution Control Board (CPCB) ( $200\mu\text{g}/\text{m}^3$ ) at all the locations. The concentration of RSPM varied from  $286.5\text{--}421.4\mu\text{g}/\text{m}^3$  at different locations across the city. This poses a serious threat to environment and human health of the people living in and around the city. This can be supported by the findings from the study by Kazimuddin and Banerjee (2000) reported that more than 10,000 premature deaths occurred in Kolkata in 1995 due to SPM. The concentration of Pb (Lead) in the blood was found to be  $25.6\mu\text{g}/\text{dl}$  in Kolkata compared to  $6.0\mu\text{g}/\text{dl}$  in Tokyo, (Misra and Khandekar, 1994). These conditions can be improved by adopting the following strategies: the main arterial road pothole-free, footpaths and widening the roads wherever possible should be given top priority. The proportion paved road space to the total space in Kolkata is only 6% compared to Delhi—20%, Mumbai—16% whereas ideally it should be 25–30%. Improved practices for managing traffic can reduce congestion significantly. Improvements could include such incentives and disincentives as restricting use of main arteries, encouraging car pooling, providing incentives to use public transport, improving public transit system or establishing new ones, taxing cars entering the city limits, imposing steeper parking fees, and imposing an environmental tax on automobiles.

**4.5 Mumbai:** As a result of the industrial and commercial development there has been a consistent influx of migrants from all over the country resulting into increase in population growth. The population of Mumbai has recorded a phenomenal increase after Independence. The present population has crossed the 10 million and further growth is projected. In spite of the stringent pollution control norms are being laid down and are followed meticulously, like Delhi the up gradation to CNG vehicles for public use such as taxies and Buses is followed appropriately, degradation of ambient air quality is being observed over the past years. The concentration of PM has been of

major concern as the city dwellers have to face clouds of dust emitted by the vehicles during the traffic jams. The major cause of this air pollution is related to increase in number of vehicles and second major factor is the taxies which are more than 10 years old and in bad state of maintenance. Inadequate road and traffic network unable to meet the needs of the increasing population, leading to traffic congestion and traffic jams. Such areas and traffic intersections are regions of high levels of pollution.

In spite of all the major polluting factors, a decreasing trend has been observed in ambient NO<sub>2</sub> (Fig. 6) levels which may be due to various measures taken such as introduction of Euro-III norms etc.

## 5. Interpretation of the extended survey for Mumbai city:

As discussed earlier about the extended survey for the city of Mumbai, the selected sampling location was situated at the Dr. Annie Besant road, as it has high vehicular traffic and is a major road located near the Worli junction. The aim of the study was to find the correlation between the vehicle density at peak hours during the morning and formation of ground level ozone in the afternoon period.

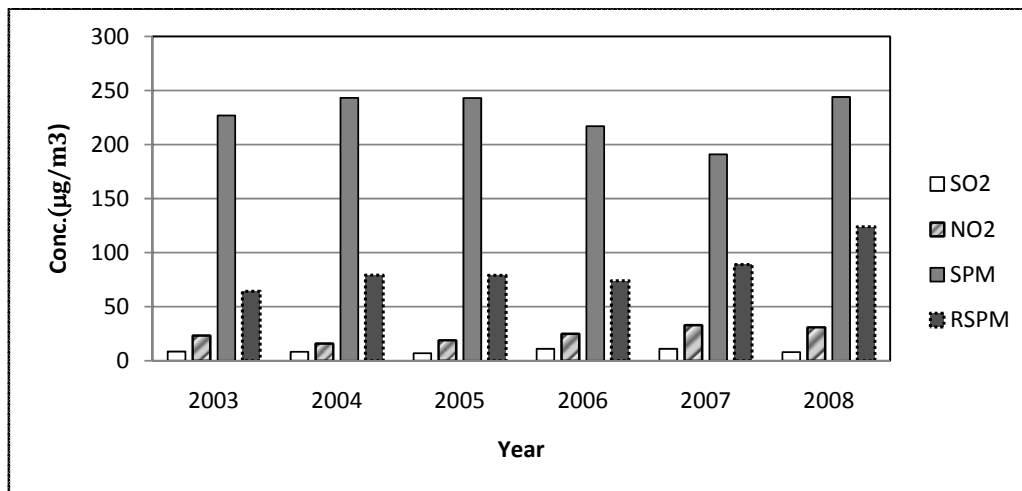


Figure 6 Concentration of criteria pollutants in Mumbai.

Source: NEERI

This is because, if in the peak hours of morning the vehicular load is high then the vehicles are bound to emit larger amounts of VOCs (Volatile Organic Carbons) and NO<sub>x</sub> which are the primary pollutants responsible for the formation of ground level ozone (WHO 1998).

The sampling was conducted from 8<sup>th</sup> May to 30<sup>th</sup> May 2009 (coincides with peak summer). Along with ground level ozone, NO<sub>x</sub> (Oxides of Nitrogen), SO<sub>x</sub> (Oxides of Sulphur), SPM (Suspended Particulate Matter), and RSPM (Respirable Suspended Particulate Matter) were also analyzed. A Vehicular survey was conducted to support the assumption. The survey for the vehicles was conducted during the peak hours of morning, i.e. from 8 a.m. to 12 noon, as the vehicle moving during the specified time slot will be influencing the formation of ground level ozone during the later afternoon hours, according to the hypothesis. Vehicles moving from the Worli junction towards J. J. Hospital were counted. The concentrations of ground level

ozone were monitored continuously from 8<sup>th</sup> May 2009 to 30<sup>th</sup> May 2009. The concentrations of ground level ozone were recorded for hourly average values.

## 6. Data and Analysis

Fig. 7 depicts the daily flow of vehicles on the Dr. Annie Besant road, whereas the fig.8 shows the ground level ozone concentrations for the week during which vehicle counting was carried out. It was observed that for the days of monitoring the concentration of have never exceeded the permissible limit (WHO of 100-200  $\mu\text{g}/\text{m}^3$  per hour or USEPA standard of 75 ppb per hour), the ozone values observed were in the range of 0.01to 51.89 ppb. As the number of vehicles increase, it should encourage formation of ground level ozone, but the trend observed in the study shows the other way. Hence, more comprehensive study has to be carried out in order to understand the phenomenon of lower concentrations of ground level ozone.

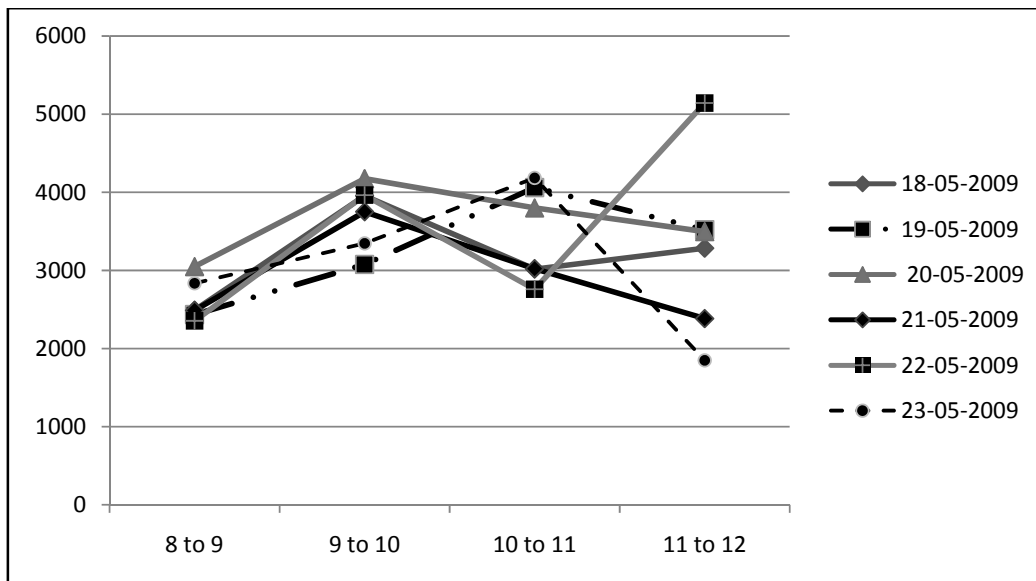


Figure 7 Number of Vehicles during the peak hours

## 7. Discussion:

- From the above study it can be concluded that the hypothesis of high vehicular density during the peak hours cannot be substantiated with formation of ground level ozone in the later hours.
- There may be other aspects such as metrological conditions (wind, humidity, etc.), salinity content of air, etc., which may be affecting the formation of ground level ozone.
- The observation further brings to the fore front that ozone levels remain much below the prescribed limits by the WHO and USEPA. Hence, at present ground level ozone is not an alarming threat to plant, animal or human health.
- Further investigation is required to study the causes of non-formation of ground level ozone formation and to hypothesize whether it is a general phenomenon across the urban regions across the country.

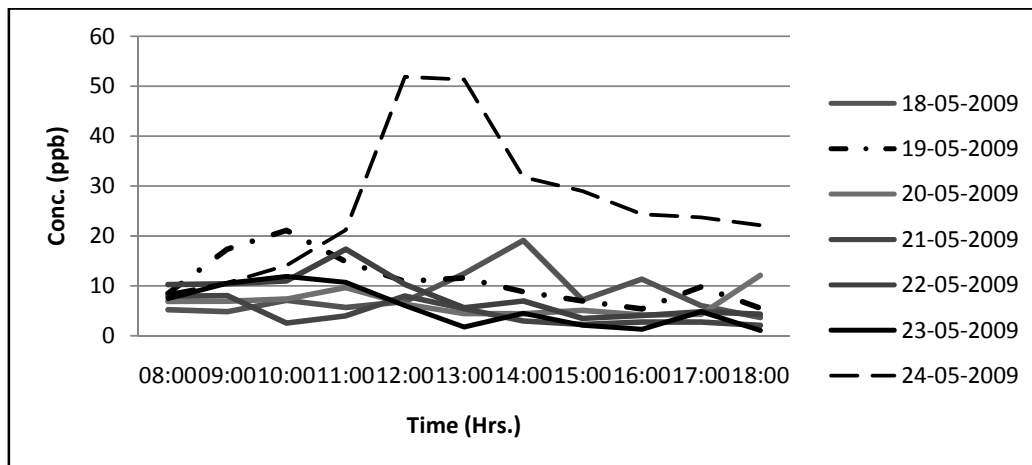


Figure 8 Trends for ground level ozone during the period of vehicle counting

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